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Vacuum Pipe Heating in RHIC

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Introduction

[Note by Peggs:] This RAP note is an almost completely literal transcription of an unpublished note with the same title that was originally written by A.G. Ruggiero in July 1987. My contribution has largely been to type the original into the computer, and to slightly modify the nominal parameters used in the sample calculations.

Vacuum Pipe Heating

Assume M equally spaced bunches of the same shape and population with gaussian longitudinal distribution. If N_b is the number of particles per bunch, σ_L is the rms bunch length, and P is the total power dissipated, then

$$P = \frac{1}{2}\sum_{n=1}^{\infty} R_{nM}\, I_{nM}^2 \qquad (1)$$

where R_{nM} is the wall resistance at the nM harmonic and I_{nM} is the beam current at the nM harmonic. That is,

$$I_{nM} = 2\, I_{ave}\, exp\left(-\frac{1}{2}n^2\alpha^2\right) \qquad (2)$$

where

$$\alpha = \frac{M\sigma_L}{R_0} \qquad (3)$$

and the average radius $R_0 = 610.175$ m. The average current is given by

$$I_{ave} = \frac{ZN_b e\beta cM}{2\pi R_0} \qquad (4)$$

where Z is the charge state.

The consideration following the way described in given RAP report

above the critical frequency. The critical resistance R_c used in these expressions is given by

$$R_c = \frac{R_0}{b}\rho^2\left(\frac{\sigma}{l}\right) \tag{10}$$

where $b = 34.6$ mm is the vacuum chamber radius, assuming a circular geometry.

Symbol	Units	Stainless Steel	Copper
n_c (M = 57)		1.4×10^{10}	22
n_c (M = 114)		0.7×10^{10}	11
R_c	[Ω]	6.04×10^6	8.2

Table 2: More parameters for stainless steel and copper, at 4.2 K cryogenic temperatures.

Table 2 shows that the anomalous skin depth effect is important for copper, but irrelevant for stainless steel.

The total power dissipated is found by combining equations 1 and 2

$$P = 2I_{ave}^2 \sum_{n=1}^{\infty} R_c \left(\frac{n}{n_c}\right)^p exp\left(-n^2\alpha^2\right) \tag{11}$$

where

$$p = 1/2 \qquad n \leq n_c \tag{12}$$

and

$$p = 2/3 \qquad n > n_c \tag{13}$$

Obtained result for power load (at 10^{11} particles per bunch):